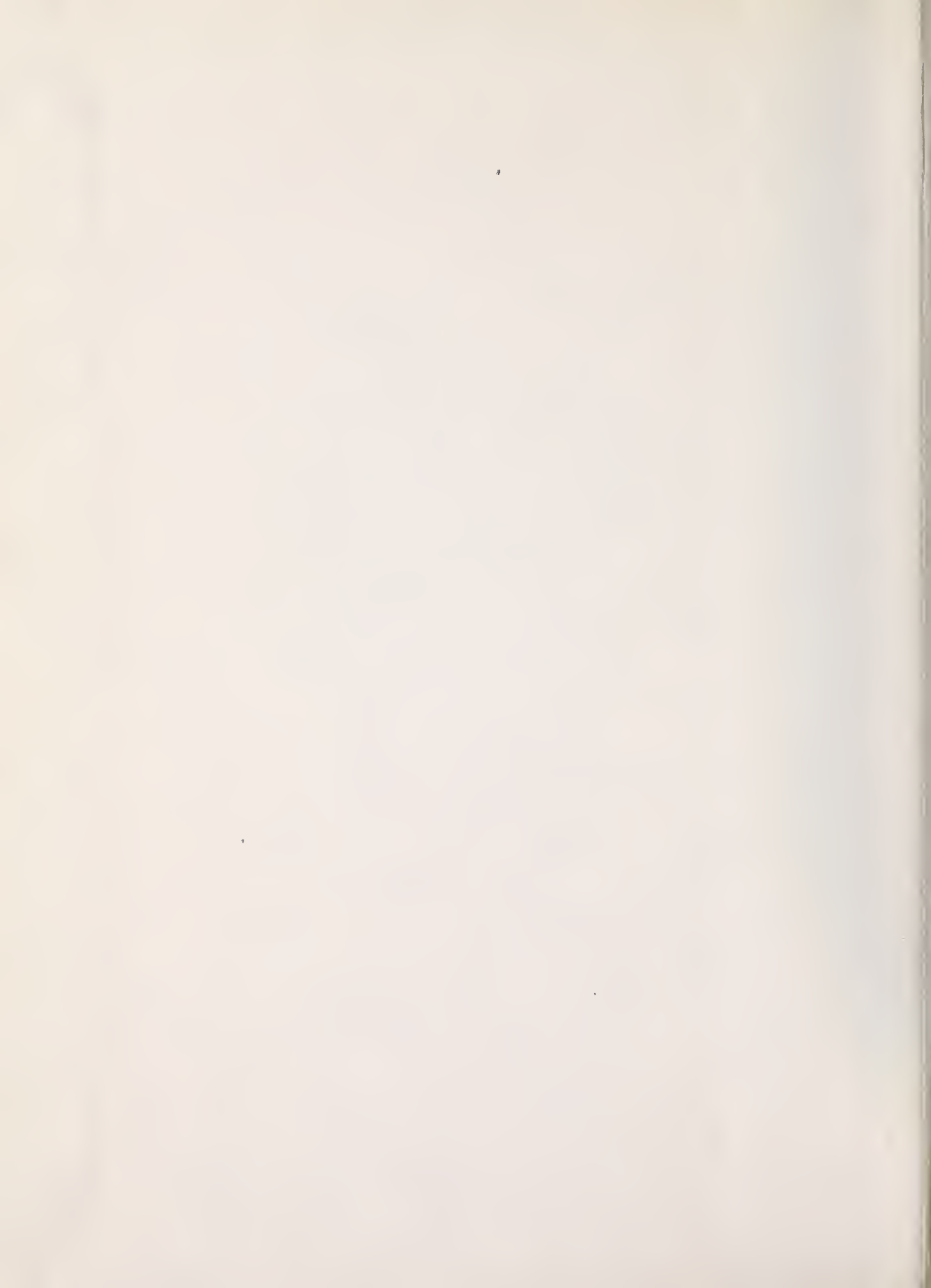


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Manual and Computerized Footprint Identification

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No. 712

1972

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Manual and Computerized Footprint Identification

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National Bureau of Standards
Washington, D.C. 20234



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Manual and Computerized Footprint Identification

by J. H. Wegstein

Part 1 describes a manual footprint classification system that utilizes the ridge patterns adjacent to the toes on the sole of the right foot. This system is an extension of the FBI footprint classification system. Part 2 describes a method of coding minute details of these prints for storage in a computerized file. The computer can then search a similarly coded unknown print against this file and identify the most likely matching prints from the file.

Key words: Computerized-footprint-identification; footprint; pattern recognition.

Introduction

For personal identification, the use of fingerprints is the most common and most developed technique. However, other dermatoglyphic areas on palms, toes and soles of the feet can also serve to uniquely identify an individual.¹ This paper describes an identification system utilizing the sole print of the right foot. The area of the sole starting at the base of the toes and running for about 70 mm toward the heel is used. Prints may be obtained by inking and pressing the sole on a flat surface or by internal reflection photography utilizing a light source, prism, and camera.² The latter resulting high-contrast image resembles an inked print. This principle applies when one observes, through a glass of water, the prints of the fingers holding the glass. Figure 9 was made from an internal reflection photograph and shows the area of the sole that is used.

If a technician is given two dermatoglyphic prints of the same area, such as the soles of the feet, he can immediately tell by inspection of the prints whether they are from the same person. In making this identification, he utilizes minute details in the prints, particularly, ridge endings and bifurcations in the ridges that are hereafter referred to as minutiae.

When an unknown print is to be searched against a file of prints, making a positive identification is a minor problem compared to the task of finding the matching print in the file. To facilitate finding a print in a file, it is classified using the gross patterns that occur in the ridges. The resulting classification is then used to locate the print in the file. The classification of a search print should agree closely enough with the classification of a file print that only a few prints from the file need to be compared with the search print.

The remainder of this paper is divided into two parts. Part 1 describes a system for manually classifying, filing, and searching prints from the right foot. Part 2 describes a method of coding and storing right-footprint information in a computer memory so that a computer can identify an unknown footprint by comparing its code with other codes previously stored in its memory or mass store.

Part 1.

Manual Classification and Search

The manual classification system is a modification and extension of the Federal Bureau of Identification footprint classification system described in two issues of the FBI Law Enforcement Bulletin.^{3,4} It is assumed that the reader who wishes to classify footprints will study these references. The precise definition of cores, deltas, and major pattern types requires further study of the basic FBI manual on fingerprints⁵.

The complete classification for right-foot prints described here consists of three parts labeled PS, DST, and FIN. The classification for four typical prints appear as follows:

<u>PS</u>	<u>DST</u>	<u>FIN</u>
O2	nu	-
La	m	22
Ww	mW	12
Wd	u	8

PS, short for Primary-Secondary, refers to the eight different patterns of ridges that occur on the ball of the foot immediately below the great toe. These are:

- O1 Ridges are plain arches that tend to flow from toe to heel.
- O2 Ridges are plain arches that tend to flow across the foot.
- La Loops where staples point toward the toes.
- Lb Loops whose staples point toward the great-toe side of the foot.
- Ld Loops whose staples point toward the right and toward the heel of the foot.
- Ww Whorls
- Wd Double loops.

Wx Patterns that do not conform to any of the above types--called accidentals.

Schematic diagrams for these types of patterns are shown in Figures 1 and 2. These diagrams merely summarize the more elaborate FBI rules for primary-secondary pattern definition.

The classification system described here is intended to handle a larger file than the FBI system was designed to handle and differs from the FBI system as follows. The FBI classification includes only parts labeled PS and FIN for the right foot along with similar parts for the left foot. The system described here utilizes only the right footprint but includes an extra part called DST that makes use of the patterns in the remainder of the distal part of the sole. The ridge pattern on the interdigital pads below the toes may include no loops or it may include combinations of loops whose staples point up or down. A loop is considered to occur if at least one ridge recurves to form a staple. The various possible patterns are shown schematically in Figure 3 along with their DST designations. To elaborate on Figure 3, two or more downward pointing staples are designated M. Two or more upward pointing staples are designated ω . When upward and downward pointing staples both occur, it is immaterial whether they do or do not form a whorl.

The part of the classification called FIN is the distance in millimeters between a core and delta of the PS pattern (if a core occurs). The line along which FIN is measured is shown schematically as a fine straight line in Figures 1 and 2. Note that types 01 and 02 have no FIN number. In Ld, Ww, and Wd type prints where there are two deltas, the distance is measured from the upper delta to the core. The core point used is defined as the point on the innermost curving ridge where the curvature is greatest. In La type prints FIN is measured from the core to the delta on the great-toe side of the sole of the foot. In Wd type prints there are two cores and FIN is measured from the upper delta to the nearest core. Some additional examples of type Wd prints are shown in Figure 4 along with core-delta lines.

In the FBI system the FIN (or "final") part of the classification is obtained by counting the number of ridges that occur between the core and the delta. An FBI classification of a print is entirely topological in nature and is invariant to the size of the print. It does not change during the time an individual grows from a baby to a mature person. In contrast, the system described here is intended for use on prints from mature persons. The core-delta distance, in millimeters, is not expected to change significantly and, accordingly, it is used in lieu of the more difficult-to-obtain ridge count. The complete classification for the footprint shown in Figure 9 is: Ww nw 21.

Prints are filed in the PS sequence shown in Figures 1 and 2. Within each PS group the prints are filed in the DST sequence shown in Figure 3. And, finally, within each DST group the prints are filed in numerical order as indicated by FIN. Only those prints of good enough quality to be classified should be filed.

When an unidentified print is to be searched against the file, it is classified according to the above rules. It is then compared with prints having the same classification from the file. It must also be compared with neighboring prints from the file whose FIN values differ from that of the search print by as much as two or three millimeters plus or minus. If the search print is of such poor quality that there is an uncertainty in the value of PS or DST, then other prints from the file corresponding to possible PS and DST values of the search print must also be examined. In comparing prints a technician notes agreement in peculiarities of ridge patterns, but he makes final decisions based on exact correspondences of minutiae patterns. Creases, scars, and other marks that may be of a temporary nature are ignored.

Part 2

Codification and Computerized Search

Digitalized descriptive information suitable for use by a computer is obtained from specific areas adjacent to cores in the PS region of the footprint. Such an area might appear as shown in Figure 5. Ridges are observed in a clockwise direction from left to right and minutiae are given coded values, θ , as follows. Ridge-endings such as minutiae b, e, and g in Figure 5 have a value $\theta = 0$. Ridge-beginnings such as minutiae a and d have a value $\theta = 1$. Since a splitting of one ridge into two ridges such as minutia j might appear as a ridge-beginning if the print were less heavily inked, it too is given a value $\theta = 1$. Similarly, merges in ridges such as c are given the value $\theta = 0$ as though they were ridge endings. Breaks in ridges like f that are shorter than the distance between two ridges are ignored. Short ridges like i that are shorter than the distance between two ridges are also ignored. Incipient ridges like h are ignored. Ridges that "kiss" or touch briefly as at k are not coded.

Each minutia that is given a θ value is also given coordinate values x and y by superimposing a rectangular grid over the area as shown in Figure 6. The grid units are 0.5 mm and the grid covers an area of 15 mm x 10 mm. The grid is oriented so that the x axis passes through a delta and is tangent to the innermost recurving ridge of a core at the point $x = 15$. One convenient way to read minutiae data is to project the print with a ten power opaque projector. A suitably enlarged grid is then placed on the projected image. The positioning of the grid for each of the different PS pattern types is shown in Figure 7. Figure 8 shows

the grid position to use on the illustrated variant of type La. To read minutiae data, one first locates each minutia as illustrated in Figure 5 then records the nearest x, y coordinates along with θ . The data corresponding to Figure 6 appears as follows:

<u>x</u>	<u>y</u>	<u>θ</u>
15	01	0
13	01	0
13	02	1
16	02	1
18	02	0
14	03	0
16	03	0
14	04	1
16	04	1

The number of minutiae per footprint that are recordable in this manner ranges from 5 to about 25. A set of data like this for each footprint along with its identification and classification (PS, DST, FIN) is read into a computerized file. The rather rare types 01 and 02 that have no core are not handled by this system.

When an unknown footprint is to be identified, its minutiae data are recorded as above and read into the computer. The computer compares this data from the unknown print with each set of data in its file and computes a score indicating how well the two prints match. The computer then prints the identification and classification of those file prints having the highest matching scores. A technician then compares the unknown print with each print from the file that the computer has indicated to be a possible match.

The algorithm used by the computer in comparing footprints is shown in flow diagram form in Figure 10. It is a slightly simplified version of the M19 matcher described in National Bureau of Standards Technical Note 538⁶. Here IMX is the number of minutiae in a print; Ident is the identification of the print including its classification; and array A contains the values x, y, and θ as shown at the bottom of Figure 10. Corresponding minutiae are used in making the identification, but they need not coincide. The tolerated amount of displacement is determined by the parameters LS and KR.

This work was performed at the NBS Center for Computer Sciences and Technology and was encouraged by the Center's Director, Dr. Ruth M. Davis. The author is also indebted to Mr. John Rafferty of NBS and to Mr. Alan Meyrowitz of the Special Action Office for Drug Abuse Prevention for testing this footprint identification system. He also appreciates the advice received on footprint identification problems from Mr. H. Caton of the Federal Bureau of Identification.

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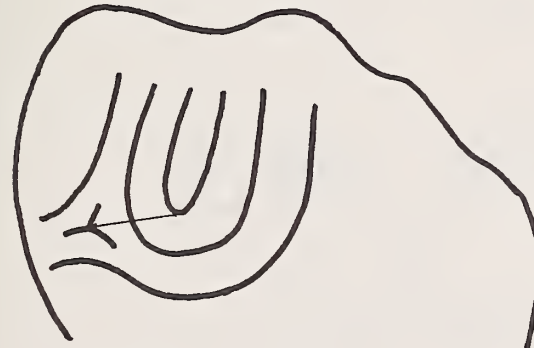
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01



02



La



Lb

Figure 1. PS Pattern Designations



Ld



Ww



Wd



Wx

Figure 2. PS Pattern Designations (Continued)



Figure 3. DIST Pattern Designations



Wd

Figure 4. Core-Delta Lines on WD Prints

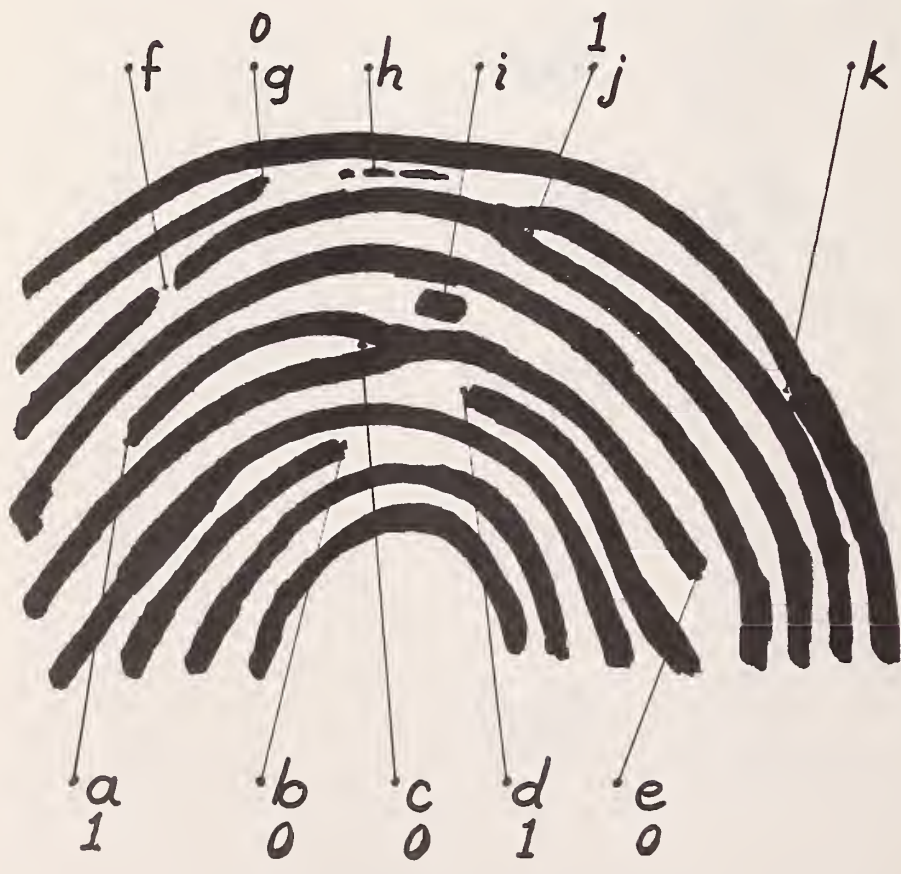


Figure 5. Minutiae Identifications

Figure 6. Grid for Reading Minutiae Data

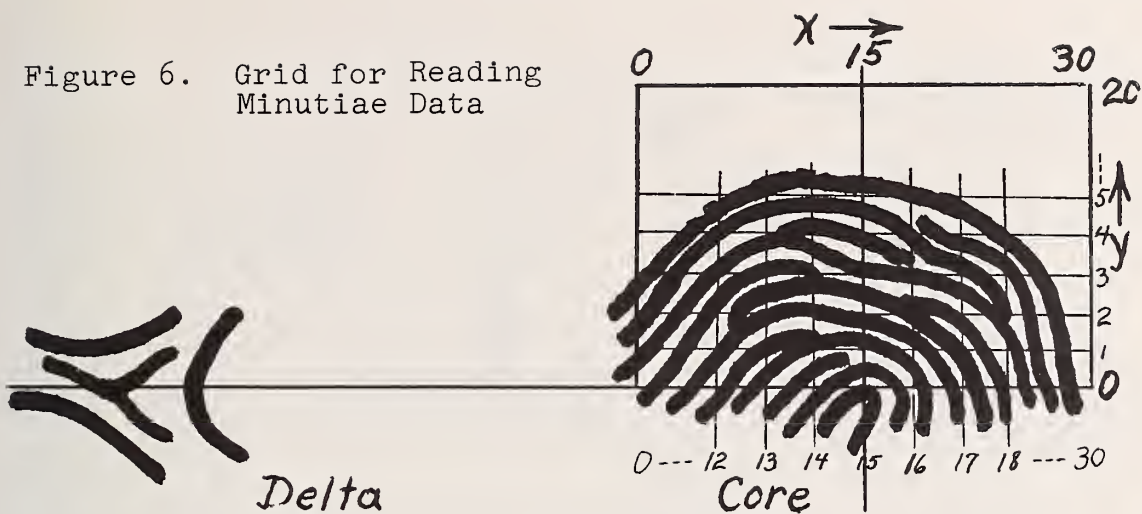


Figure 7. Placement of Grid on Various Types of Prints

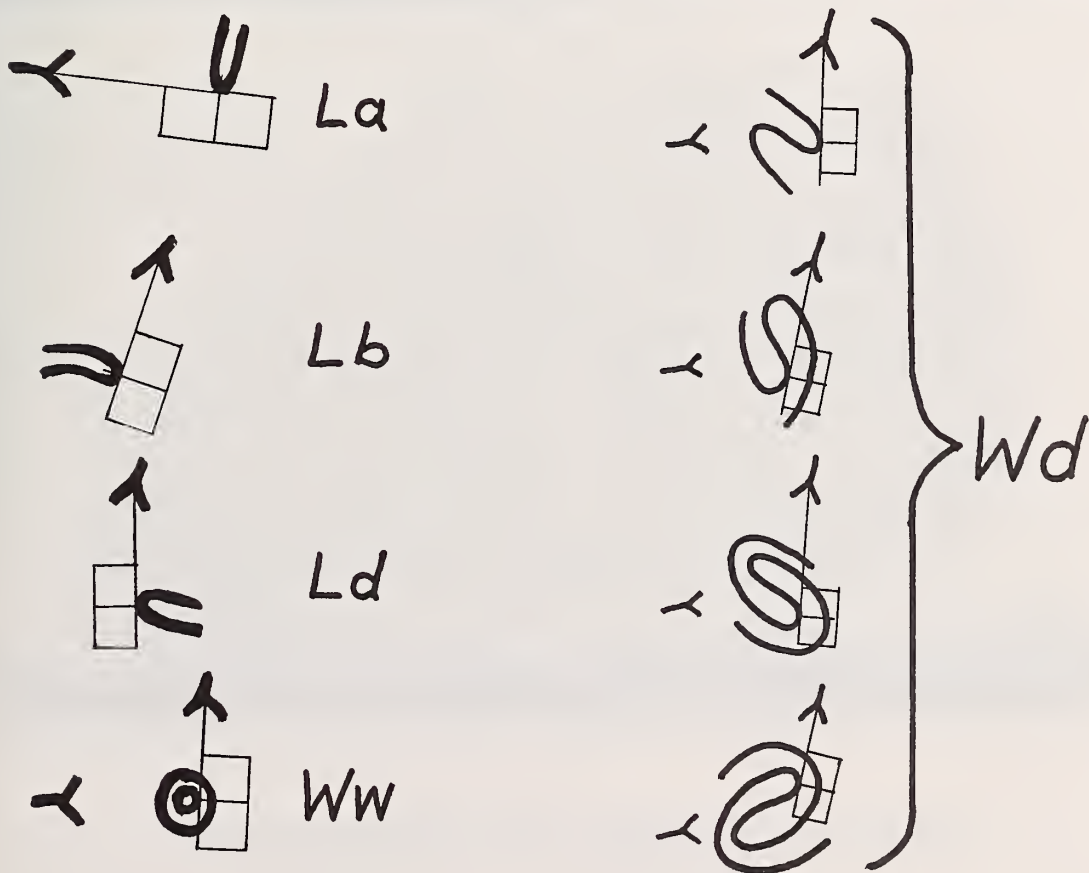




Figure 8. Grid Placement on Variant La Print

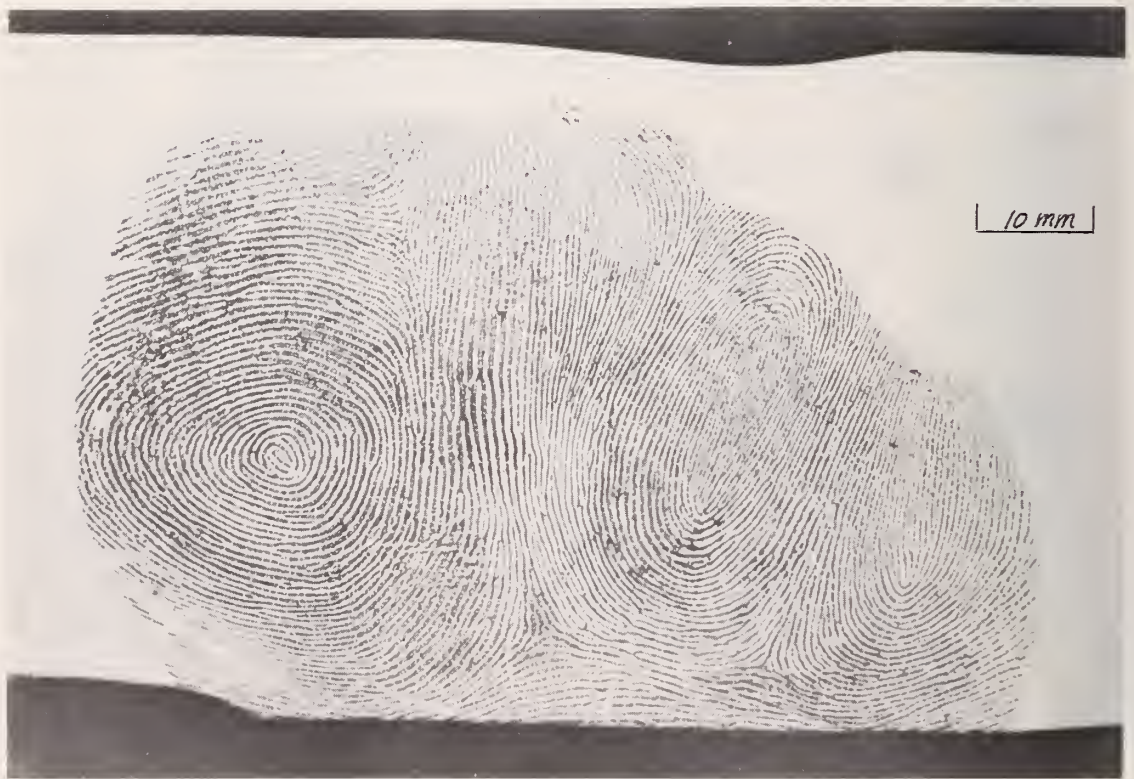


Figure 9. Footprint with Classification:
Ww nw 21

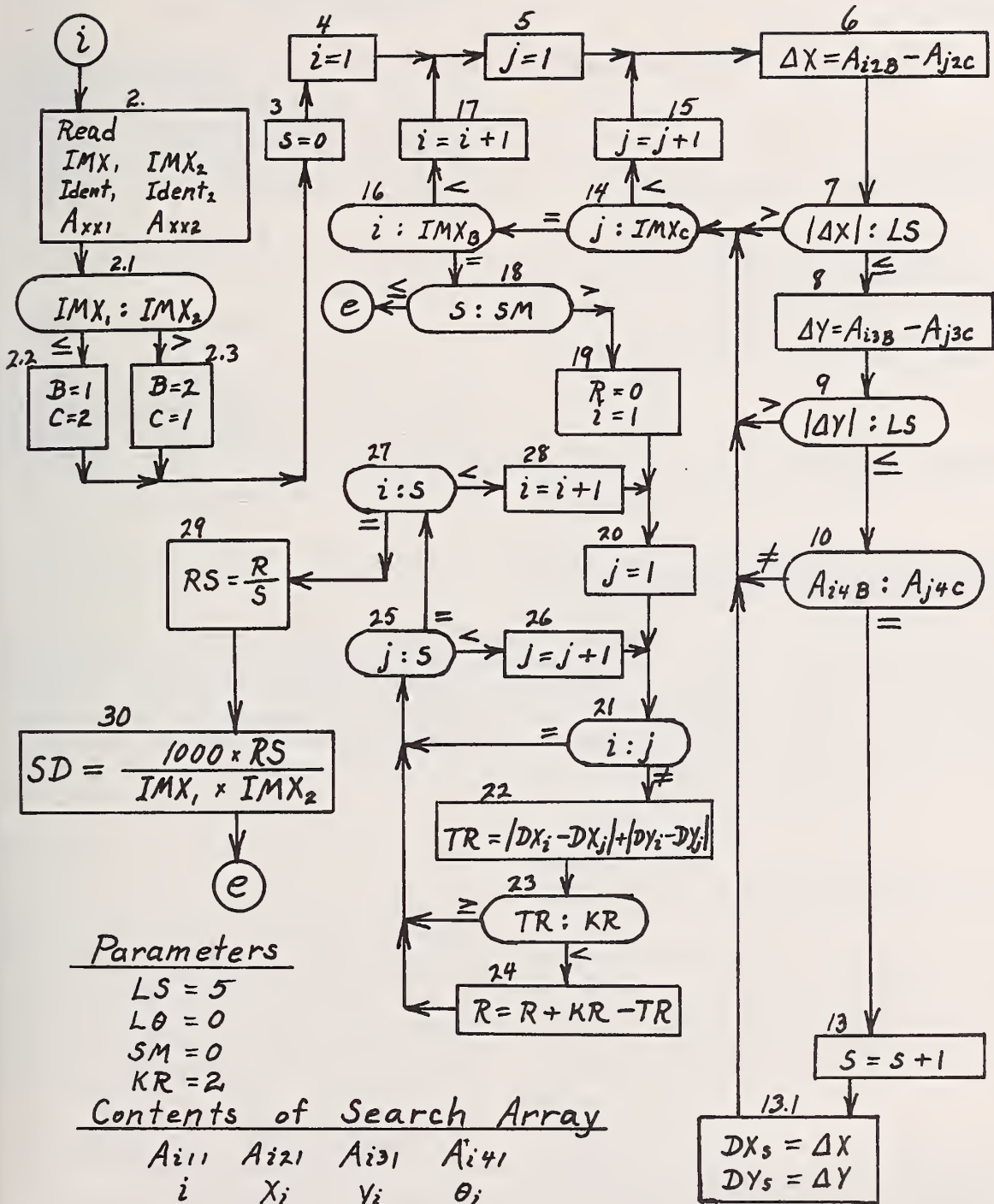


Figure 10. Footprint Matching Algorithm

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